

The Technological Background of Hybrid Electric Vehicles

True electric vehicles offer the promise of 100% zero-emissions operation; however, the high-energy batteries needed to allow these vehicles to offer the practical driving range and performance demanded by consumers are considered a longer-term development. Hybrid electric vehicles (HEVs), which combine heat engines and fuel tanks with electric propulsion systems, offer the possibility of greatly reducing emissions and fuel consumption while offering consumers the level of performance with which they are familiar. Advanced propulsion technologies are key to the success of HEVs and to the realization of these advantages. The basic technologies needed to produce a viable first-generation HEV prototype are near the final stages of development; significant systems integration and applications engineering efforts required to produce a practical vehicle are underway.

Since no definitive HEV model yet exists, there are a number of competing and complementary technologies which could potentially be utilized in a commercial HEV propulsion system. In addition,

there are a wide array of potential HEV configurations, creating a virtually infinite number of component variations.

All HEVs also require a hybrid power unit (HPU), sometimes referred to as a main power *unit* depending on the way it is used in the system. Combustion engines are usually considered for these units. Possible HPU technologies for use in an HEV include the compression ignition, direct-injection; Stirling; or gas turbine engines. Fuel cells, which generate electricity from hydrogen and oxygen, are a longer-term HPU possibility.

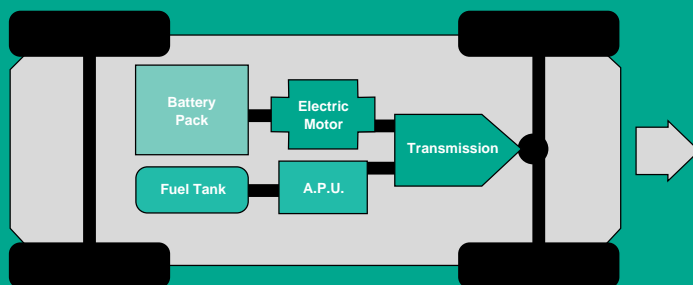
In addition, all HEVs require sophisticated drivetrain components such as motors, inverters, power electronics, and regenerative braking systems.

One classification of the wide array of HEV configurations divides them into two general categories: *parallel* and *series* designs.

A parallel HEV is configured with two power paths, so that either the HPU engine or the electric propulsion system—or both—can be used to produce the motive power to turn the wheels. In one

approach, the electric-only mode can be used for short trips. For longer trips, the engine would provide primary power to the vehicle, with the electric motor assisting during hill climbs, fast acceleration, and other periods of high energy demand. In such a vehicle, the engine can be downsized in relation to a similar-sized conventional vehicle, providing greater rel-

Parallel Hybrid Configuration



The Technological Background of HEVs

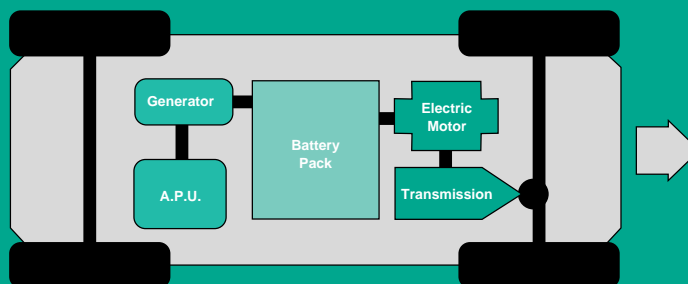
active fuel economy. In addition, there is less need to maximize on-board battery storage capabilities, allowing additional weight advantages.

In a series HEV, a small fuel-burning engine directly drives an alternator to generate electricity. The electricity is then stored in the batteries or sent to the electric motor, which then powers the wheels. The vehicle can operate in zero-emissions mode, and when the batteries are drained to a certain level, the engine turns on and begins to recharge them. Since it is less dependent on the vehicle's changing power demands, the engine can operate within a narrower and more efficient range of speeds.

Another way to classify HEVs is by the relative size of their conventional and electric propulsion systems. A *power-assist* configuration is driven primarily by a larger engine, with a smaller battery storage capacity. A *range-extender* configuration has a relatively larger battery capacity and a smaller engine used primarily for an on-board recharge or "limp home" capability. A *dual-mode* balances the two, with engine and battery sized to allow the vehicle to run comfortably on all electric or all engine power, or some combination of the two. Power-assist hybrids are generally in a parallel configuration, and range extender HEVs are usually in a series configuration.

As suggested, all HEVs have smaller engines and burn less fuel than a comparable conventional vehicle. In addition, synergies created by combining the two propulsion systems allow HEVs to recapture some of the energy lost in braking and store it in the battery for later use. This *regenerative braking* is responsible for a significant portion of the HEV's fuel

Series Hybrid Configuration



economy improvement. Electronic controllers create a balance between the systems to select the most efficient mode of operation at each point. The engine also may be shut off completely under some operating conditions. The end result for the near-term is a vehicle capable of providing 100% better mileage than a comparable gasoline-only vehicle.

The construction of a basic HEV is currently within reach, but just as with the conventional automobile, R&D will continue to improve HEVs in terms of performance, cleanliness and driver comfort. Government and industry engineers are working together and separately, investigating a host of enabling technologies as well as systems integration techniques. The state-of-the-art is moving forward in HEV-enabling areas including high-rate energy storage devices; cost-effective, high-efficiency power electronics; and fuel-efficient, low-emission engines. Cost-reducing techniques are also of primary concern.

For additional information, contact:



Rogelio A. Sullivan
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
(202) 586-8042

